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# THE CONNECTION BETWEEN COGNITIVE AND AFFECTIVE DIMENSIONS OF PLANT AWARENESS IN RELATION TO UNDERSTANDING THE COOLING FUNCTIONS OF VEGETATION

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**Abstract.** *Plant Awareness is a multidimensional construct that reflects the level of an individual's perception, understanding, and valuation of plants. Enhancing Plant Awareness is vital for conserving biodiversity and promoting sustainability, given the frequent neglect of plants' ecological roles. This study analyzes the relationship between the cognitive (knowledge) and affective (attitudes) dimensions of Plant Awareness, influenced by a teaching intervention focused on the role of plants in cooling the local climate. Using a pre-test/ post-test and experimental/ control group design, 201 Czech students aged 13–15 engaged in project-based learning. The experimental group measured the cooling effect of the plants in the field using thermovision, while the control group received information solely in the classroom from the teacher. For the study, a self-constructed instrument to measure attitudes towards plants was developed (Cronbach's α = .85/ .86). Results indicated a significant positive correlation between knowledge and attitudes after intervention, highlighting the interconnectedness of these dimensions of Plant Awareness. The experimental group demonstrated improvements in both dimensions, whereas the control group showed only slight knowledge gains and a decline in attitudes. This study emphasizes the necessity of integrating climate-related functions of vegetation into education through hands-on experiences and modern technology to foster Plant Awareness.*

**Keywords:** *plant awareness, plant cooling, plant knowledge, attitudes toward plants*

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## Introduction

Plants are fundamental to human survival and the functioning of the biosphere. Yet, paradoxically, plants are often overlooked, due to a phenomenon widely known as Plant Blindness (Wandersee & Schussler, 1999) or, more recently, reframed as Plant Awareness Disparity (Parsley, 2020), describing human ignorance of plants and their environmental role. This cognitive and affective disregard toward plants has been identified as a significant barrier to fostering sustainability (Amprazis & Papadopoulou, 2020; Howard et al., 2022). The neglect of plants reduces societal appreciation of their ecological services and, in turn, weakens the willingness to protect and sustainably manage ecosystems. This negative phenomenon was recently positively reframed as Plant Awareness (Pany et al., 2022). In this light, strengthening Plant Awareness has become a key challenge for science and environmental education.

Educational researchers increasingly emphasize the need to conceptualize Plant Awareness as a multidimensional construct (Stagg et al., 2025). Parsley et al. (2022) have distinguished four dimensions of Plant Awareness Disparity: Attention, Knowledge, Attitudes, and Relative Interest. Also, Panny et al. (2022) have described four dimensions: Attention, Knowledge, Attitudes, and Categorization of plants as living organisms. Recently, Dünser et al. (2024a) have validated the Plant Awareness construct as „a multidimensional construct that reflects the level of an individual's perception, understanding, and valuation of plants" Dünser et al., 2024a, p. 1065) and have distinguished three dimensions: Attitudes, Understanding, and Attention. While definitions vary, most frameworks converge on two core dimensions: knowledge (the understanding of plants, their biology, functions, and ecology) and attitudes (interest, values, and emotional connection toward plants) (Dünser et al., 2024a; Pany et al., 2022; Parsley et al., 2022; Stagg & Dillon, 2022). Knowledge and attitudes are not independent variables, and their interconnection can significantly influence the outcomes of environmental education (Frick et



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al., 2004; Roczen et al., 2014). It is therefore important to investigate both variables simultaneously, not only in terms of their individual development, but also their association, which may reveal the effectiveness of various teaching approaches.

Previous research suggests that, within the Plant Awareness construct, the dimensions of knowledge and attitudes are closely interrelated: higher levels of botanical knowledge are frequently associated with more positive attitudes toward plants (Fančovičová & Prokop, 2011; Pedrera et al., 2023). Conversely, emotional interest may foster motivation to acquire botanical knowledge (Pany et al., 2019). However, it is still unclear how this relationship operates and to what extent targeted educational interventions can influence it (Stagg et al., 2025).

Pedagogical interventions are considered among the significant factors affecting Plant Awareness (Dünser et al., 2024a). Outdoor and project-based activities have proven effective for improving both knowledge and attitudes, as they provide direct experiences with plants and their functions (Fančovičová & Prokop, 2011; Činčera & Holec, 2016; Pany et al., 2019). These experiences allow learners to connect theoretical concepts with real-world phenomena, leading to deeper conceptual understanding and emotional engagement with the natural environment (Rickinson et al., 2004). In contrast, classroom-based or mediated instruction, while useful, may yield weaker attitudinal outcomes due to its lower experiential value (Tseng et al., 2013).

Several studies have shown that Plant Awareness increases when learners are exposed to the significance of plants for human life. Pany et al. (2019) have emphasized the role of medicinal plants and spices as effective contexts for fostering Plant Awareness. A study by Dünser et al. (2024b) has highlighted a potential positive impact of plant ecosystem services (i.e., benefits, which plants provide for humans (Millennium Ecosystem Assessment [MEA], 2005)), on students' attitudes towards plants, suggesting that these benefits may foster a greater appreciation of plants. One particularly underrepresented yet highly relevant ecosystem service of plants is the cooling of the local climate. Through evapotranspiration, vegetation acts as a biological air-conditioning system: plants use solar energy primarily for water vapor (transpiration from plant bodies, evaporation from soil they cover), thereby cooling the surrounding environment (Ellison et al., 2017; 2024). This cooling effect not only reduces urban heat stress but also sustains short water cycle, mitigating droughts and contributing to water security (Ellison et al., 2017; Kravčík et al., 2008). Despite its importance, this topic is rarely emphasized in formal science education, and both students and pre-service teachers have been shown to lack sufficient understanding of these processes (Ryplová & Pokorný, 2018; 2019; 2020).

Given the urgent challenges posed by global climate change, embedding the cooling effect of vegetation into curricula could offer a powerful way to connect plant education with sustainability issues. This integration could allow students to understand the ecological significance of vegetation beyond theoretical concepts. It also provides an authentic context for examining how knowledge and attitudes interact within the framework of Plant Awareness.

### *Research Problem*

Despite the recent advancements in the theoretical construct of Plant Awareness, a comprehensive understanding of the correlation between its cognitive (knowledge, understanding) and affective (attitudinal) dimensions remains elusive. Although such correlations have been noted (Pany et al., 2022), there remains a significant gap in understanding whether specific, vital content areas for humans, such as the climate-related functions of plants, can effectively enhance both dimensions simultaneously. Current science education tends to underrepresent the ecological functions of vegetation in regulating local climate and the short water cycle (Ryplová & Pokorný, 2018; 2020). Consequently, students may lack awareness of how plants contribute directly to climate change adaptation and mitigation, undermining the development of sustainable worldviews. The question remains whether, and to what extent, insufficient understanding of this vegetation function may be associated with less positive attitudes toward plants.

### *Research Focus*

This study, therefore, focuses on the potential of educational interventions regarding the cooling effect of plants to enhance Plant Awareness among lower-secondary school students. Specifically, it has examined whether targeted intervention can improve knowledge about processes related to plant cooling mechanisms and whether such knowledge gains are accompanied by positive shifts in attitudes. The educational approach is further examined by comparing two modes of project-based learning. The first one involves field activities, where students engage directly with plants and utilize thermal imaging cameras along with other modern digital tools to measure the


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cooling effect of vegetation. The other mode is indoor project-based learning, which lacks direct interaction with plants and students' own measurement. In this context, the study has explored the effectiveness of experiential engagement with plants and their climate-related functions in enhancing both cognitive understanding (knowledge) and emotional connection (attitudes), ultimately contributing to a greater Plant Awareness.

### *Research Aim and Research Questions*

The aim of this study was to explore the relationship between students' knowledge and attitudes toward plants, in the context of a targeted educational intervention that focuses on the cooling benefits of vegetation. Based on this aim, the following research questions were formulated:

1. Does the educational intervention significantly increase students' knowledge and attitudes toward plants in the experimental group?
2. Are there significant differences in the development of knowledge and attitudes between the experimental group, which was in direct contact with vegetation and verified the cooling function of plants through its own measurements, and the control group, which obtained the same information only indirectly from the teacher?
3. Is there a statistically significant correlation between the increase in knowledge and the change in attitudes in the experimental group?

## **Research Methodology**

### *General Background*

The validated Plant Awareness construct is relatively new (Dünser et al., 2024a). Currently, there is a lack of instruments capable of thoroughly assessing its various dimensions, which necessitates further research and remains a topic of substantial scientific discourse. Notably, evaluating the cognitive dimension (understanding, knowledge) has proven particularly challenging (Dünser et al., 2024a). To address this gap, self-developed research instruments were employed. This approach aims to contribute to the ongoing scientific discussion on effective strategies for evaluating Plant Awareness and its dimensions.

The study adopted a quasi-experimental research design with pre-test and post-test control groups to analyze the relationship between students' knowledge and attitudes in the context of an educational intervention focused on the cooling function of vegetation. It was carried out in the spring of 2025 in eight classes of students aged 13 – 15 at Czech lower-secondary schools (ISCED level 2) and corresponding grades of a multi-year grammar school. The research followed a quantitative approach within the theoretical framework of experiential and project-based learning, which emphasizes the role of direct experience in developing both knowledge and attitudes towards plants.

The experimental group participated in project-based learning that included fieldwork, during which students directly experienced the cooling effects of vegetation by conducting their own measurements with modern instruments, including a thermal imaging camera, an infrared thermometer, and a solar meter. The control group participated in a similar project-based lesson, but without fieldwork, hence without immediate contact with vegetation and without the opportunity to observe its cooling capacity through their own measurements. The necessary values for the activity were obtained from prepared images, including thermographic visualizations. Both groups were taught by the same teacher. Quantitative data were collected online through structured tests assessing knowledge and attitudes before and after the intervention. To assess the evolution of the intervention's impact on the experimental group over time, a second post-test was conducted two weeks after the initial intervention. While this timeframe was insufficient for a comprehensive evaluation of long-term teaching effects, the data collected may reveal trends in the development of knowledge and attitudes toward plants. This information could serve as a basis for future research aimed at understanding the sustainability of these observed variables.

### *Sample*

The research sample consisted of 201 lower secondary school students (ISCED 2) from four schools (eight classes) in the Czech Republic, aged 13 – 15 years old ($M$ = 13.79). The sample size was determined by the number of students enrolled in the participating schools who agreed to take part in the study. They were randomly divided into an experimental group ($N$ = 108) and a control group ($N$ = 93). The division followed existing class groupings


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to maintain the natural school setting. The sample included 105 girls, 86 boys, and 10 students who identified as another gender. The experimental and control groups were comparable in terms of gender distribution, previous biology education, and general school performance. All participants were informed about the nature of the study, and consent was obtained from schools and legal guardians in accordance with ethical research standards. All participants and their legal guardians were informed about the purpose and procedures of the study, and written consent was obtained from guardians before data collection. Participation was voluntary, and all data were collected and analyzed anonymously. The study was conducted in accordance with institutional ethical standards and approved by the Ethics Committee of the Faculty of Education, University of South Bohemia in České Budějovice.

*Instrument and Procedures*

As a research instrument, this study employed a self-constructed online questionnaire designed to measure students' knowledge and attitudes toward plants. An introductory demographic part included questions on students' gender, age, place of residence, and experience with plants in the home environment. The knowledge section included multiple-choice questions and short open-ended questions adapted from previous studies conducted by the authors (Ryplová & Pokorný, 2019; 2020), focusing on plant processes related to the cooling function, particularly the use of solar energy by plants, the process of transpiration, and its ecological significance. Each knowledge item was scored by 1 point. The attitude section consisted of statements rated on a 5-point scale, reflecting students' interest in plants and their appreciation of plants' ecological functions. Each level of the ascending scale was assigned a score ranging from 1 to 5. Three of the attitude statements were adapted from the Dünser et al. (2024b) attitude questionnaire. Additional items were adapted from the physics attitude questionnaire developed by Kaur and Zhao (2017). In general, the attitudes section included ten items targeting the emotional, cognitive, and behavioral dimensions of students' relationship with plants (e.g., preferences regarding the number of plants at school, interest in learning about plants, subjective feelings when surrounded by plants, and the perceived importance of plants for everyday life). Open-ended follow-up questions accompanying attitude items allowed respondents to elaborate on their ratings and provided deeper insight into their relationship with plants.

The maximum number of points in the knowledge part was 8 (seven questions, one of them having two parts, each awarded by 1 point), and the maximum number of points in the attitude part was 50 (ten questions). The questionnaire was administered three times: as a pre-test before the educational intervention, as a post-test immediately after the intervention, and as a delayed post-test approximately 14 days later, to assess the development of the intervention's effect over time. The same instrument was used in both the experimental and control groups. The complete version of the questionnaire is available in the Appendix.

All testing phases, including both the teaching activities and the online assessments, were conducted during regular school hours under the supervision of teachers. To ensure comparable conditions, both the experimental and control groups completed the tests in their regular classrooms or school gardens using their own mobile phones or school tablets. The presence of teachers ensured that students worked independently and that their responses were not influenced by external assistance. The validity of the questionnaire was evaluated by three independent experts – a secondary school biology teacher, a specialist in biology education (didactics), and a plant biology expert. This review process ensured that the instrument was both scientifically accurate and pedagogically appropriate for the target group.

To verify the reliability of the instrument, Cronbach's alpha coefficients were calculated separately for the knowledge and attitude sections in pre-tests and post-tests (see Table 1). The pre-test version of the knowledge test (8 items) showed low reliability (Cronbach's $\alpha = .44$). One item (Question: Plants have/ do not have the ability to thermoregulate.) displayed a near-zero item–total correlation and was therefore removed from further analyses. After its removal, internal consistency improved to $\alpha = .52$. In the post-test (with the revised 7-item version), Cronbach's alpha further increased to $\alpha = .62$, indicating improved internal consistency over time. The attitude scale demonstrated consistently high reliability, with Cronbach's alpha of $\alpha = .85$ in the pre-test and $\alpha = .86$ in the post-test. These values confirm that the attitude instrument was psychometrically sound throughout the study, while the knowledge test reached acceptable reliability for exploratory research purposes. Although the knowledge section showed lower reliability, this was expected given that the instrument covered a broad range of plant-related concepts rather than a single homogeneous construct. Therefore, a lower alpha does not necessarily indicate a weakness of the instrument but rather reflects its multidimensional nature (Tavakol & Dennick, 2011).



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**Table 1**
*Reliability of the Research Instrument*

| Subscales | Cronbach-α |
|---|---|
| Pre-test knowledge | .52 |
| Pre-test attitudes | .85 |
| Post-test knowledge | .62 |
| Post-test attitudes | .86 |

*Data Analysis*

A linear mixed-effects model was applied to analyze the relationship between attitudes and knowledge. Individual students were included as a random effect to account for the dependence between their pre-test and post-test results. The fixed effects included the total knowledge score, group, school, gender, and the interaction between group and test type (pre-test vs. post-test). The knowledge variable was used to assess the extent to which students' attitudes were associated with their level of knowledge. Group, school, and gender were incorporated as covariates to explain differences between categories of respondents. The interaction between group and test captured potential changes in attitudes between pretest and posttest across groups. The general form of the model can be expressed as:

*Attitudes ~ Knowledge + Group + School + Gender + Group:Test + (1 |Student)*

Including the student as a random intercept allowed us to account for the longitudinal dependence in the data. Although the dependent variable was measured on a scale, the large sample size and the central limit theorem justified the use of this approach. Residual diagnostics did not indicate substantial heteroscedasticity, supporting the suitability of the chosen model for the data. The analyses were conducted in R using the *lme4* package (Douglas et al., 2015).

In addition to the linear mixed-effects model, used to analyze the relationship between attitudes and knowledge, the data were further processed using *Statistica* 14.0 (TIBCO Software Inc.). These analyses focused primarily on assessing the internal consistency of the research instrument, testing the assumptions of normality, and comparing knowledge and attitude scores across time points and groups.

Before conducting further analyses, the distribution of the data was examined for normality using the Shapiro–Wilk test. The test was applied separately to knowledge and attitudes, and for both the control and experimental groups in the pre-test and post-test phases. The results indicated that the knowledge data did not follow a normal distribution in any group or testing phase ($p < .05$). In contrast, the attitude data were normally distributed in all cases ($p > .05$). Based on these results, non-parametric methods were used for knowledge data and parametric methods for attitude data in the subsequent analyses. Table 2 shows the W statistic and p-values obtained from the Shapiro–Wilk test.

**Table 2**
*Results of the Shapiro–Wilk Test for Normality of Knowledge and Attitude Scores in Experimental and Control Groups (Pre-Test and Post-Test Phases)*

| Group | Phase | Variable | *W* | *p-value* | *Normality* |
|---|---|---|---|---|---|
| Experimental | Pre-test | Knowledge | .88 | < .001 | No |
| Experimental | Pre-test | Attitudes | .99 | .69 | Yes |
| Control | Pre-test | Knowledge | .91 | < .001 | No |
| Control | Pre-test | Attitudes | .99 | .66 | Yes |
| Experimental | Post-test | Knowledge | .95 | < .001 | No |


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| Group | Phase | Variable | *W* | *p-value* | *Normality* |
|---|---|---|---|---|---|
| Experimental | Post-test | Attitudes | .99 | .76 | Yes |
| Control | Post-test | Knowledge | .95 | < .001 | No |
| Control | Post-test | Attitudes | .97 | .08 | Yes |

Based on the results of the normality tests, non-parametric Wilcoxon signed-rank tests were used to analyze changes in knowledge within groups over time, while paired sample *t*-tests were used for attitudes. To compare the differences between the experimental and control groups, independent sample *t*-tests or Mann–Whitney U tests were applied as appropriate.

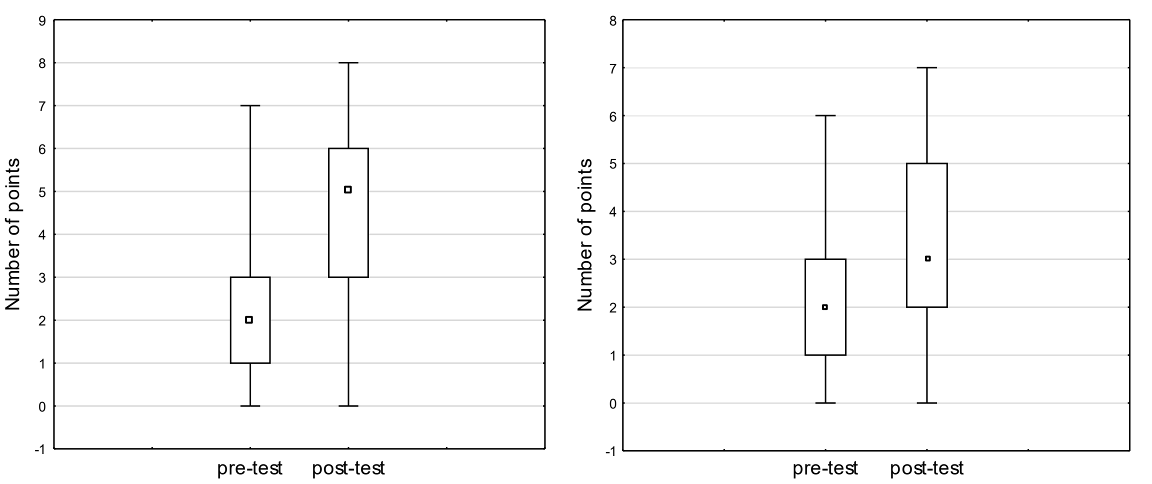
Finally, a linear mixed-effects model was employed to examine the relationship between knowledge and attitudes. This approach allowed us to assess whether an increase in knowledge was associated with more positive attitudes toward plants in the ecological context of transpiration, while simultaneously accounting for repeated measurements within students. Effect sizes were calculated using partial omega squared ($\omega^2_p$), which quantifies the proportion of variance in the dependent variable uniquely explained by each predictor after controlling for other predictors (Olejnik & Algina, 2003). Values of 0.01, 0.06, and 0.14 can be interpreted as small, medium, and large effects, respectively (Cohen, 1988).

## Research Results

### Comparison of Students' Knowledge and Attitudes

In the experimental group, a statistically significant increase in knowledge was observed after the intervention (Wilcoxon signed-rank test: $Z = 7.60$, $p < .001$, $N = 97$). The average knowledge score in the pre-test of the experimental group was 2.33, with a median of 2; in the post-test, the average score increased to 4.48, and the median reached 5. In the control group, a significant increase in knowledge was also observed (Wilcoxon signed-rank test: $Z = 5.37$, $p < 0.001$, $N = 71$). The average knowledge score in the pre-test of the control group was 2.23, with a median of 2; in the post-test, the average score increased to 3.25, and the median reached 3. Box plots in Figure 1 show the changes in knowledge in the experimental and control groups.

**Figure 1**
*Box Plots of Knowledge in the Experimental (Left) and Control Group (Right)*




*Note.* □ Median; ▯ 25–75 %; |— Min–Max

Students' attitudes towards plants improved significantly in the experimental group (paired *t*-test: $t(107) = -3.84$, $p = .0002$). The mean attitude score in the pre-test was 28.35 (*Mdn* = 28), while in the post-test it



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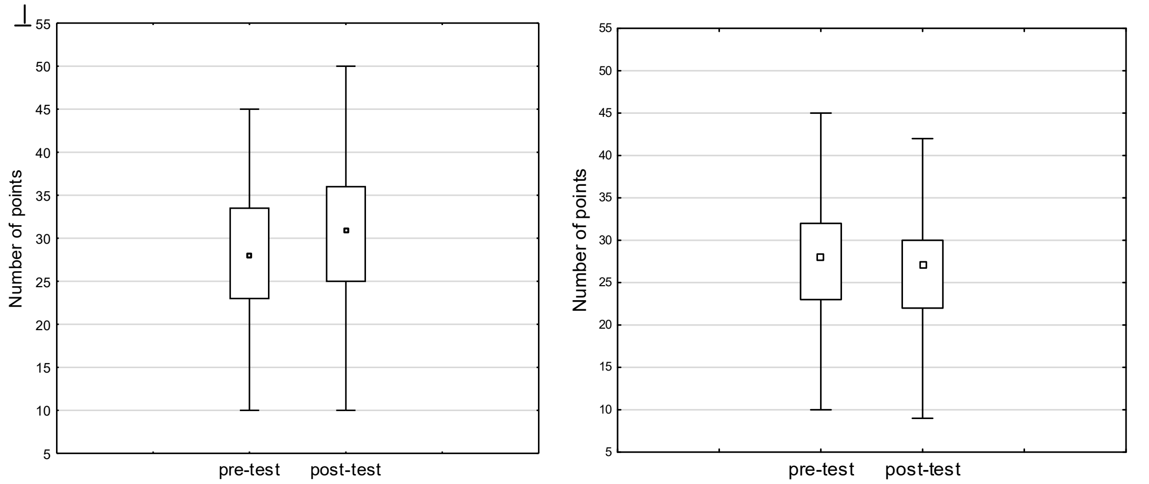
increased to 31.05 (*Mdn* = 31). A statistically significant change in attitudes was also observed in the control group (paired t-test: $t(92) = 3.73$, $p = .0003$), although the difference in means was smaller compared to the experimental group and in the opposite direction. In the control group, the mean pre-test score was 27.76 (*Mdn* = 28), but it decreased to 26.00 (*Mdn* = 27) in the post-test. Box plots in Figure 2 illustrate the changes in students' attitudes in both the experimental and control groups.

**Figure 2**

*Box Plots of Attitudes in the Experimental (Left) and Control Group (Right)*




*Note.* ▫ Median; ▯ 25–75 %; |— Min–Max

To assess the differences between the experimental and control groups after the intervention, the Mann–Whitney U test was used for knowledge scores ($Z = 4.29$, $p < .001$), and an independent *t*-test was used for attitudes ($t = 5.09$, $p < .001$). Both results indicate a statistically significant difference between the groups in favor of the experimental group (see Table 3).

**Table 3**

*Comparison of Knowledge and Attitude Scores Between the Experimental and Control Groups*

| Group | Test | *N* | *Statistic* | *p-value* |
|---|---|---|---|---|
| Knowledge experimental vs. control | Mann-Whitney *U* | 108/93 | $Z = 4.29$ | < .001 |
| Attitudes experimental vs. control | *t*-test | 108/93 | $t = 5.09$ | < .001 |

*Comparison of Students' Knowledge and Attitudes*

The analysis using the linear mixed-effects model revealed that knowledge had a statistically significant positive effect on students' attitudes ($\beta = 0.64$, $p < .001$). Higher levels of knowledge were thus associated with more positive attitudes toward plants. The results further indicated differences between the experimental and control groups. In the control group, attitudes significantly declined from pre-test to post-test ($\beta = -2.39$, $p < .001$), whereas in the experimental group, a trend toward improvement was observed ($\beta = -1.33$, $p = .065$), although this change did not reach statistical significance.

These findings suggest that the intervention may have positively influenced students' attitudes in the experimental group, while attitudes in the control group became more negative over time. A full overview of the parameter estimates, standard errors, *t*-values, and *p*-values of the linear mixed-effects model is presented in Table 4. This table illustrates how the model accounted for knowledge, group membership, and other covariates, providing transparency regarding the overall model structure and its explanatory power. Estimates represent the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regression coefficients (unstandardized β) obtained from the linear mixed-effects model. *SE* is the standard error of the estimate. The results of the linear mixed-effects model are graphically illustrated in Figure 3.

**Table 4**

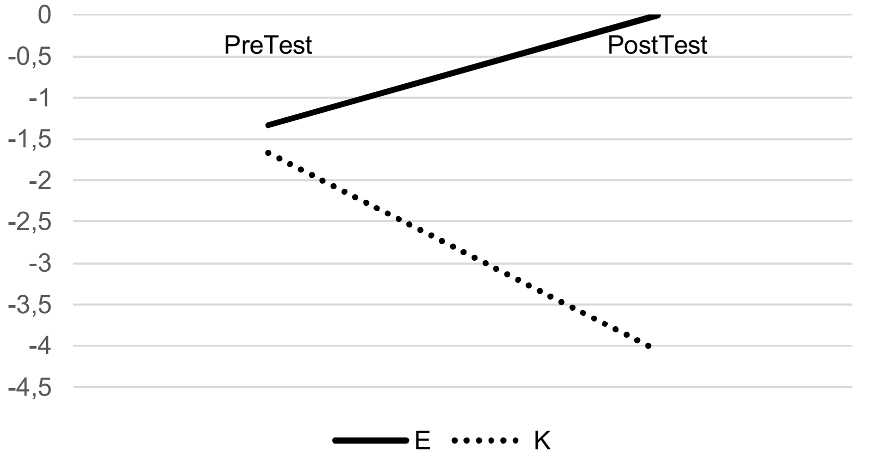
*Parameter Estimates of the Linear Mixed-Effects Model for Attitudes*

| Parameter | Estimate | SE | t value | p value |
|---|---|---|---|---|
| Intercept | 29.73 | 1.39 | 21.33 | < .001 |
| Knowledge | 0.64 | 0.19 | 3.29 | .001 |
| Control group | –4.06 | 1.17 | –3.47 | .001 |
| School 1 | 2.67 | 1.45 | 1.84 | .066 |
| School 2 | –2.71 | 1.43 | –1.90 | .058 |
| Male | –3.08 | 0.90 | –3.43 | .001 |
| Other gender | –5.67 | 2.03 | –2.80 | .005 |
| Experimental group x pretest | –1.33 | 0.72 | –1.85 | .065 |
| Control group x pretest | 2.39 | 0.66 | 3.60 | < .001 |

*Note.* Estimate = Regression Coefficients (Unstandardized β); SE = Standard Error of the Estimate

**Figure 3**

*Graphical Representation of the Linear Mixed-Effects Model Results*




*Note.* The Experimental Group - E, Black Line; the Control Group - K, Dashed Line). The x-Axis Represents the Test Phase (Pre-Test and Post-Test), and the y-Axis Represents the Predicted Attitude Score (Higher Values Indicate More Positive Attitudes Toward Plants

The analysis of variance indicated that knowledge significantly predicted attitudes ($p = .001$, $\omega^2_p = .03$), suggesting a small-to-medium effect size. Gender also had a notable influence ($p < .001$, $\omega^2_p = .07$), while the interaction between group and test showed a moderate effect ($\omega^2_p = .07$) (see Table 5). Partial omega squared ($\omega^2_p$) represents the proportion of variance in the dependent variable uniquely explained by each predictor after controlling for other factors. Values of $\omega^2_p = .01$, .06, and .14 are typically interpreted as small, medium, and large effects, respectively (Cohen, 1988; Olejnik & Algina, 2003).


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**Table 5**

*Partial Omega Squared Effect Sizes for Fixed Effects in the Linear Mixed-Effects Model*

| Predictor | $\omega^2_p$ | 95% CI | Interpretation |
|---|---|---|---|
| Knowledge | .03 | [.01, 1.00] | Small-medium |
| Group | .04 | [.01, 1.00] | Small-medium |
| School | .04 | [.00, 1.00] | Small-medium |
| Gender | .07 | [.02, 1.00] | Medium |
| Group x Test | .07 | [.02, 1.00] | Medium |

*Note.* $\omega^2_p$ = Partial Omega Squared; 95% CI = 95% Confidence Interval; the Range of Values that is Likely to Contains the True Population Effect Size

The analysis of individual attitude items revealed that the intervention had a differentiated impact on specific aspects of students' affinity for plants. The detailed results for each attitude item are presented in Table 6. Negative $\beta$ values indicate higher post-test scores compared to pre-test (i.e., an increase in attitudes), as the variable *TestPre* was coded as 1 for pre-test and 0 for post-test ($p < .05$ = *, $p < .01$ = **, $p < .001$ = ***, *ns* = not significant).

**Table 6**

*Effects of the Educational Intervention on Individual Attitude Items (Parameter Estimates for the Interaction Group E: TestPre in the Linear Mixed-Effects Model)*

| Item | Attitude statement (abbreviated) | ß (GroupE:TestPre) | *p*-value | Significance | Direction of change |
|---|---|---|---|---|---|
| P1 | Positive feelings toward plants | 0.031 | .786 | ns | no change |
| P2 | Considering plants important | –0.043 | .684 | ns | no change |
| P3 | Aesthetic perception of plants | 0.066 | .544 | ns | no change |
| P4 | Feeling comfortable among plants | 0.328 | .021 | * | decrease |
| P5 | Interest in observing and learning about plants | –0.350 | .003 | ** | increase |
| P6 | Perceiving learning about plants as useful for life | –0.431 | < .001 | *** | increase |
| P7 | Enjoyment of tasks and experiments with plants | –0.260 | .031 | * | increase |
| P8 | Perceiving learning about plants as changing worldview | –0.039 | .765 | ns | no change |
| P9 | Preference for number of plants at school | –0.225 | .185 | ns | no change |
| P10 | Interest in general plant knowledge | –0.169 | .171 | ns | no change |

Significant improvements in the experimental group were observed particularly for items related to subjective experiences and active engagement with plants, such as interest in observing and learning about plants during free time (P5), perceiving learning about plants as useful for life (P6), and enjoyment of solving tasks and conducting experiments with plants (P7). These items showed a statistically significant increase in attitude scores after the intervention. In contrast, P4 showed a statistically significant change, but it the opposite direction. The overall scores as well as some other items (e.g., preferences regarding the number of plants at school or perceiving learning about plants as changing one's worldview) did not demonstrate significant change. The results, therefore, suggest that the intervention had the strongest effect on the practical, experiential, and value-related dimensions of attitudes toward plants, whereas the cognitive component remained relatively stable.

Item-level analyses (P1–P10) revealed small to moderate effects ($\omega^2_p$ = 0.00–0.11), with gender and the group × test interaction showing the strongest contributions (see Table 7). Partial omega squared ($\omega^2_p$) quantifies the proportion of variance in the dependent variable uniquely explained by each predictor after controlling for other factors. Values of $\omega^2_p$ = 0.01, 0.06, and 0.14 are interpreted as small, medium, and large effects, respectively (Cohen, 1988; Olejnik & Algina, 2003). All values are based on Type III ANOVA results from the linear mixed-effects model.



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**Table 7**
*Partial Omega Squared ($\omega^2_p$) Effect Sizes for Individual Attitude Items (P1–P10)*

| Item | Knowledge | Group | School | Gender | Group x Test | 95% CI range (approx.) |
|---|---|---|---|---|---|---|
| P1 | .04 | .02 | .02 | .06 | .00 | [.00, 1.00] |
| P2 | .04 | .00 | .08 | .08 | .00 | [.00, .15] |
| P3 | .00 | .00 | .00 | .10 | .00 | [.00, .15] |
| P4 | .02 | .00 | .00 | .11 | .02 | [.00, .16] |
| P5 | .02 | .02 | .00 | .04 | .05 | [.00, .12] |
| P6 | .01 | .03 | .00 | .00 | .07 | [.00, .14] |
| P7 | .00 | .00 | .03 | .00 | .01 | [.00, .06] |
| P8 | .02 | .00 | .04 | .02 | .00 | [.00, .10] |
| P9 | .00 | .01 | .00 | .00 | .01 | [.00, .05] |
| P10 | .03 | .00 | .07 | .00 | .00 | [.00, .12] |

### *The Effect of the Intervention in the Experimental Group over Time*

The post-test was administered two weeks after the intervention to assess short-term effects and early retention of attitudinal changes. A short-term interval was chosen to capture immediate reactions to the learning experience before longer-term factors, such as forgetting or external influences, could alter the results. This time frame allowed students to consolidate newly acquired knowledge and attitudes, while still minimizing the influence of external factors that may emerge over longer periods. Such an interval is often considered optimal for detecting immediate learning outcomes and short-term attitude shifts in educational settings (Reschke et al., 2024).

The results of the second post-test, two weeks after the intervention, showed a slight decrease in knowledge scores, while attitude scores remained relatively stable. A significant difference in knowledge was found between the first and the second post-test ($Z = 2.97$, $p = .003$), suggesting a partial decline in scores over time after the intervention. Nevertheless, the median (*Mdn* post-test 1 = 4.5; *Mdn* post-test 2 = 3.5) and mean (*M* post-test 1 = 4.64; *M* post-test 2 = 3.79) values remained higher than in the pre-test, showing that the overall effect of the intervention was largely retained (see Figure 4). No statistically significant difference was found between the first and the second post-test in the attitude part ($t(57) = 1.26$, $p = .21$). Although the mean attitude score slightly decreased from post-test 1 ($M = 33.02$, $SD = 7.65$) to post-test 2 ($M = 32.00$, $SD = 7.53$), this change was not significant, indicating that students' attitudes remained stable over time.



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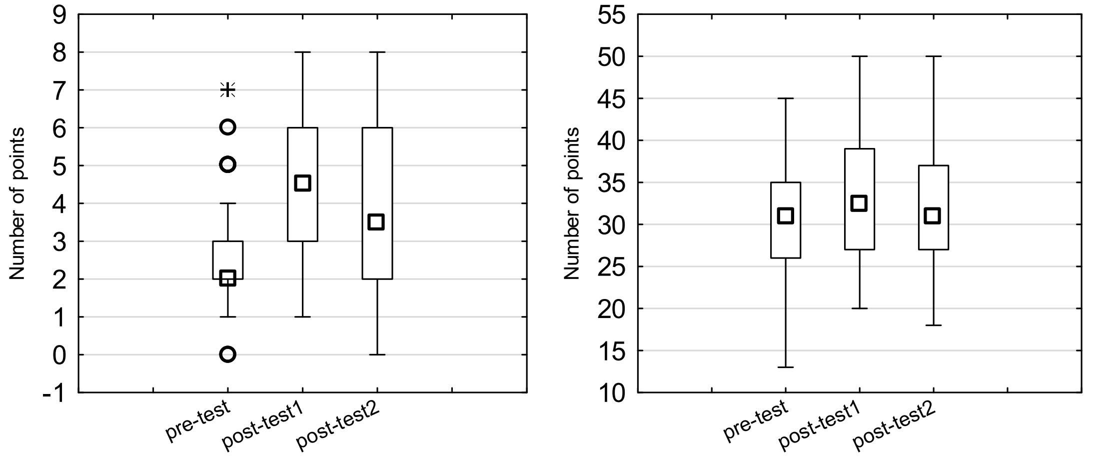
**Figure 4**
*Box Plots of Knowledge and Attitudes in the Experimental Group,*




*Note.* *N* = 58; □ Median; ▯ 25–75 %; |— Min–Max; o Outliers; * Extremes

## Discussion

The results of the pre-tests highlighted a gap in student knowledge regarding the processes associated with the cooling functions of vegetation. At the same time, the pre-test indicated a moderately positive attitude toward plants among the students. Significant gap in understanding is consistent with our previous studies (Ryplová & Pokorný, 2018; 2019; 2020).

In the post-test, an improvement was observed across most items, suggesting that students' understanding of the role of plants in the distribution of solar energy and water in the landscape had strengthened. The largest increase in correct responses occurred in Question 2 (from 12.9 % to 32.3 %), which concerned the proportion of solar energy used for photosynthesis. This result indicates that students understood that most of the incident solar energy is used by plants for transpiration (and thus cooling of the local climate), not for photosynthesis, as they had previously mistakenly believed. Improvement was also evident in Question 5 (from 10.4 % to 29.9 %, with 8.5 % of respondents achieving full marks), focused on the consequences of deforestation. This suggests that some students have developed a clearer understanding of the connections between vegetation, local climate, and the water balance in the landscape (Ellison et al., 2017).

Overall performance improved across all items, particularly in open-ended and conceptually demanding questions (e.g., Q4: from 17.9 % to 48.8 %; Q7: from 13.9 % to 54.2 %), which required a deeper understanding of processes such as transpiration (Q3, Q6) and their ecological significance. The results indicate that after the educational intervention, students show a more coherent understanding of physiological processes and their role in ecosystems. Compared to the pre-test, fewer misconceptions about the influence of plants on the water cycle and local climate were recorded, which aligns with findings from previous studies (Ryplová & Pokorný, 2018; 2019; 2020). The reason for this lack of knowledge may result from the underestimation or neglect of this topic in the Czech science curriculum. But a limited understanding of the role of plants in mitigating climate change was also reported in foreign studies (Bofferding & Kloser, 2015; Amprazis & Papadopoulou, 2020).

The educational intervention focused on the cooling function of plants had a significant effect on knowledge and was associated with changes in attitudes. In the experimental group, both these dimensions of the Plant Awareness construct improved substantially after the intervention, whereas in the control group, knowledge also increased, but attitudes declined (slightly, but statistically significantly). The key factor influencing the teaching intervention was the field component of the project-based learning. The students of the experimental group had the opportunity to engage directly with vegetation, enabling them to experience firsthand its substantial cooling effects through thermal imaging measurements. Our findings are consistent with previous studies suggesting that direct contact with plants and recognition of the importance of plants for humans has a positive effect on Plant Awareness (construct) (Stagg & Dillon, 2022). Fančovičová and Prokop (2011) documented that direct interaction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with plants can foster stronger emotional connections, increase perceived usefulness, and lead to more positive attitudes toward plant-related topics. In the context of sustainability education, hands-on experiences not only enhance cognitive understanding but also contribute to developing environmental stewardship and awareness, which are essential for achieving long-term sustainability goals (UNESCO, 2017).

Stagg et al. (2025) concluded that first-hand experience with plants leads to positive attitudes towards plants, particularly when combined with novel teaching approaches known to promote enjoyment. Project-based education is considered one of these engaging approaches (Blumenfeld et al., 1992). Project-based learning, applied in both the experimental and control groups, has been shown to have a positive effect on students' attitudes in previous research (Baş & Beyhan, 2010; Kaldi et al., 2011; Kortam et al., 2018). Although several studies have demonstrated the potential of project-based learning to enhance students' engagement and conceptual understanding, its outcomes are not always immediate or consistent (Tseng et al., 2013). The effectiveness of this approach appears to depend on the duration, structure, and quality of implementation, as well as on the teacher's experience with the method (Karaçalli & Korur, 2014). In this study, students participated in project-based activities combining field observation with digital tools, including thermal imaging, which enabled them to directly explore plant processes related to water balance and energy exchange. Such integration of experiential and technology-enhanced learning seems to support deeper conceptual understanding and may contribute to positive shifts in students' knowledge and attitudes toward plants. These results are consistent with previous findings emphasizing the benefits of well-structured project-based learning in environmental and science education (Činčera & Holec, 2016; Tatar & Robinson, 2003) and highlight the added value of modern digital technologies learning (Haglund et al., 2022).

The linear mixed-effects model revealed a statistically significant positive association between knowledge and attitudes (Estimate = 0.64, $p < .001$), indicating that students with higher knowledge levels tend to express more positive attitudes. However, the effect size was small, suggesting that knowledge alone explains only a limited proportion of the variance in attitudes. The relationship appeared slightly stronger in the experimental group, where attitudes tended to improve after the intervention, while in the control group, they decreased significantly. These findings imply that while knowledge and attitudes are related, the quality of learning experiences and student engagement likely play an important role in fostering positive attitudinal change.

The positive correlation between knowledge and attitudes, confirmed in the overall results, supports the theoretical assumption that cognitive understanding and affective components of learning are closely interconnected (Roczen et al., 2014). This suggests that educational interventions aiming to promote Plant Awareness (construct) should not only focus on enhancing knowledge but also foster students' emotional engagement. Also, Kubiatko et al. (2021) concluded that factual knowledge is essential for building positive attitudes towards plants. Similarly, Dünser et al. (2024) examined the role of plant ecosystem services and concluded that regulating ecosystem services (such as the cooling effects of vegetation in this case) may contribute to fostering positive attitudes toward plants among students.

The effect size analysis revealed that, although several predictors were statistically significant, the magnitude of their effects was small to moderate. Gender consistently accounted for the largest proportion of variance across items, suggesting that attitudinal differences between male and female students persist even after controlling for other factors. The interaction between group and test indicated that the intervention may have influenced attitude change differently in experimental and control groups, although the overall effect was modest.

A closer look at individual attitude items showed that the intervention had the strongest effect on dimensions related to emotional experience and value-based engagement with plants. Significant improvements were observed in feeling comfortable when surrounded by plants, interest in observing them during free time, perceiving learning about plants as useful for life, and enjoyment of solving tasks and conducting experiments with plants. In contrast, items of a more cognitive nature, such as preferences regarding the number of plants at school, did not change significantly. Feeling comfortable when surrounded by plants showed a significant change in the opposite direction. This indicates that the intervention particularly influences the experiential and value-related components of attitudes.

In the recently validated Plant Awareness construct (Dünser et al., 2024b), the dimension Knowledge was renamed to Understanding. The authors explain the necessity of this change by the very broad range of knowledge that, according to experts participating in the scientific discussion, should be included in the construct of Plant


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Awareness. Therefore, within the dimension Understanding, the authors distinguish between "global understanding," which is consistent across the world, and "local understanding," which refers to understanding plants within their specific surroundings. From this perspective, understanding the cooling function of vegetation clearly belongs to the category of global understanding. The cooling capacity of plants plays a crucial role in reducing the impacts of global climate change worldwide (Ellison et al., 2017; 2024).

Many recent works have assessed plant knowledge in connection with Plant Awareness in terms of the conservation of biodiversity (Pedrera et al., 2023; Balding & Williams, 2016) and therefore focused on knowledge of individual plant species (Marcos-Walias et al., 2023). However, several studies have also highlighted the importance of understanding plant processes in relation to the role of plants in mitigating the impacts of global climate change (Ryplová & Pokorný, 2020) and in achieving the SDGs (Amprazis & Papadopoulou, 2020).

Overall, the findings of this study demonstrate that implementing the topic of the cooling function of vegetation into science education through project-based learning, providing direct contact with vegetation, and supported by modern measuring technology, positively influences change to associated with both the cognitive and affective dimensions of Plant Awareness. The study revealed a statistically significant correlation between knowledge and attitudes as a result of such teaching intervention. This finding confirms that a deeper understanding of the role of plants in mitigating the impacts of global climate change (particularly their cooling function) can contribute to more positive attitudes toward plants and thereby foster Plant Awareness.

## Conclusions and Implications

The study confirmed a positive relationship between students' knowledge of the cooling function of plants and their attitudes toward plants. At the beginning of the study, students' knowledge of this essential plant function was very limited. The educational intervention focusing on the cooling effect of vegetation significantly improved knowledge and was associated with positive changes in attitudes, demonstrating that experiential learning can effectively strengthen Plant Awareness.

The most notable progress occurred in the experimental group, where students directly interacted with plants and used modern digital instruments to measure their cooling capacity. This authentic, outdoor learning proved more effective than classroom-based instruction, which did not allow direct experience of plants' life-supporting functions. The results show that such modern, experiential teaching influences not only cognitive understanding but also emotional engagement and value-based attitudes toward plants. These findings are particularly relevant in today's context of global climate change. The cooling function of plants represents a natural and sustainable way to mitigate heat stress and maintain water balance — making it a meaningful topic for sustainable education.

The results also suggest that positive attitudes in the experimental group persisted over time, although knowledge levels slightly declined. We acknowledge, however, that the interval between post-tests was relatively short, limiting conclusions about long-term effects. Future studies should therefore examine the durability of these outcomes over longer periods and with larger samples. Overall, the study highlights that direct, hands-on engagement with plants and their vital ecological functions is a powerful means of enhancing both knowledge and attitudes — thereby fostering Plant Awareness. In the course of the study, a reliable attitude questionnaire was developed (Cronbach's α = .85/ .86), providing a valuable tool for future research on plant awareness.

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## Declaration of Interest

The authors declare no competing interest.

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## Appendix

*Questionnaire.*

| Section | Item | | Response options | Notes |
|---|---|---|---|---|
| Demo-graphic and back-ground informa-tion | | Gender | ☐ Male<br>☐ Female<br>☐ Prefer not to say | |
| | | Age | ☐ 12<br>☐ 13<br>☐ 14<br>☐ 15<br>☐ 16 | |
| | | Where do you live most of the time? | ☐ In a city<br>☐ In the suburbs<br>☐ In a village<br>☐ Other … | |
| | | Do you have any plants at home (indoors or in the garden)? | ☐ Yes – indoor plants<br>☐ Yes – outdoor/ garden plants<br>☐ No | |
| | | Do you take care of plants at home or else-where (e.g., watering, repotting, gardening)? | ☐ Yes – regularly<br>☐ Yes – occasionally<br>☐ No | |
| | | Are you interested in plants in your free time? | ☐ Yes – very much<br>☐ Yes – a little<br>☐ No | |
| Knowl-edge part | Z1 | Choose the correct statement: | ☐ Plants make the landscape drier because they consume water.<br>☐ Plants retain water in the landscape by cooling and initiating the local water cycle<br>☐ Plants have no effect on the amount of water in the landscape. | 1 point |
| | Z2 | What percentage of incoming solar energy is used for photosyn-thesis? | ☐ Less than 5 %<br>☐ 5 – 9 %<br>☐ 10 – 19 %<br>☐ 20 – 49 %<br>☐ 50 – 69 %<br>☐ 70 – 100 % | 1 point |
| | Z3 | Water enters the plant body through the roots. Is there a way for water to leave the plant? | ☐ No, all the water is used by the plant.<br>☐ No, part of the water is used and the excess is stored in the plant's vacuole.<br>☐ Yes …. | 1 point |
| | Z4 | In your opinion, how and through which part of the plant is water released? | Open-ended question (only answer this question if you selected "Yes, …" in the previous question.). | 2 points (1 point for men-tioning a process, e.g., evaporation, transpira-tion, water loss, etc.; and 1 point for identifying a plant part, e.g., leaf, stoma/stomata, etc.) |
| | Z5 | What happens if a forest is cut down? | ☐ The local climate will cool because forests are dark areas on the Earth's surface that warm up the most. If we cut them down, the Earth's surface will become lighter, global warming will decrease, and there will be more water on Earth.<br>☐ More water will remain in the landscape because trees evaporate water and thus remove it from the area.<br>☐ The local climate will warm because solar energy will no longer be used for the evaporation of water from forests, but for heating the surface and the air. If water does not evaporate slowly, it will not return to the area in the form of rain and fog. As a result, there will be less water in the landscape. | 1 point |
| | Z6 | The main reason why on a hot summer day it is cooler in a park with mature trees than on a paved square is that: | ☐ Photosynthesis: Plants in the park utilize incoming solar radiation primarily for photosynthesis, thereby cooling their surroundings.<br>☐ Shade: Dense tree canopies absorb and reflect solar radiation, thereby providing shade.<br>☐ Transpiration: Plants in the park utilize incoming solar radiation primarily for the evaporation of water, thereby cooling their surroundings. | 1 point |
| | Z7 | What is the process by which plants use the largest amount of solar energy? | ☐ Transpiration<br>☐ Photosynthesis<br>☐ Respiration | 1 point |



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| | | | | |
|---|---|---|---|---|
| Attitudes part: Please rate your attitude on the following scale. | P1 | How many plants would you like to have at school? | ☐ Much fewer than now<br>☐ Somewhat fewer than now<br>☐ The same as now<br>☐ Somewhat more than now<br>☐ Much more than now | Please explain the reason for your rating on the scale. |
| | P2 | How do you feel when you are surrounded by plants? | ☐ Very uncomfortable<br>☐ Somewhat uncomfortable<br>☐ Neutral<br>☐ Somewhat comfortable<br>☐ Very comfortable | Please explain the reason for your rating on the scale. |
| | P3 | How often do you stop or slow down when passing by plants? | ☐ Never<br>☐ Rarely<br>☐ Sometimes<br>☐ Often<br>☐ Very often | Please explain the reason for your rating on the scale. |
| | P4 | When I see a plant that catches my attention, I stop and look at it. | ☐ Strongly disagree<br>☐ Somewhat disagree<br>☐ Neither agree nor disagree<br>☐ Somewhat agree<br>☐ Strongly agree | Please explain the reason for your rating on the scale. |
| | P5 | How important is it for you to learn about plants? | ☐ Completely unnecessary<br>☐ Rather unnecessary<br>☐ I don't know / neutral<br>☐ Rather important<br>☐ Very important | Please explain the reason for your rating on the scale. |
| | P6 | Learning about plants is: | ☐ Very boring<br>☐ Rather boring<br>☐ Neither boring nor fun<br>☐ Rather fun<br>☐ Very fun | Please explain the reason for your rating on the scale. |
| | P7 | In my free time, I like to observe plants and learn new things about them. | ☐ Strongly disagree<br>☐ Somewhat disagree<br>☐ Neither agree nor disagree<br>☐ Somewhat agree<br>☐ Strongly agree | Please explain the reason for your rating on the scale. |
| | P8 | I learn about plants to gain knowledge that is useful for my life. | ☐ Strongly disagree<br>☐ Somewhat disagree<br>☐ Neither agree nor disagree<br>☐ Somewhat agree<br>☐ Strongly agree | Please explain the reason for your rating on the scale. |
| | P9 | I enjoy solving fun tasks and conducting experiments with plants. | ☐ Strongly disagree<br>☐ Somewhat disagree<br>☐ Neither agree nor disagree<br>☐ Somewhat agree<br>☐ Strongly agree | Please explain the reason for your rating on the scale. |
| | P10 | Learning new facts about plants changes my view of how the whole world works. | ☐ Strongly disagree<br>☐ Somewhat disagree<br>☐ Neither agree nor disagree<br>☐ Somewhat agree<br>☐ Strongly agree | Please explain the reason for your rating on the scale. |

## References

Amprazis, A., & Papadopoulou, P. (2020). Plant blindness: A faddish research interest or a substantive impediment to achieve sustainable development goals? *Environmental Education Research*, *26*(8), 1065–1087. https://doi.org/10.1080/13504622.2020.1768225

Balding, M., & Williams, K. J. (2016). Plant blindness and the implications for plant conservation. *Conservation Biology, 30*(6), 1192–1199. https://doi.org/10.1111/cobi.12738

Baş, G., & Beyhan, Ö. (2010). Effects of multiple intelligences supported project-based learning on students' achievement levels and attitudes towards English lesson. *International Electronic Journal of Elementary Education*, *2*(3), 365–385. https://files.eric.ed.gov/fulltext/EJ1052017.pdf

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing supporting the learning. *Educational Psychologist, 26*(3-4), 369–398. https://doi.org/10.1080/00461520.1991.9653139

Bofferding, L., & Kloser, M. (2015). Middle and High school students' conceptions of climate change mitigation and adaptation strategies. *Environmental Education Research, 21*(2), 275–294. https://doi.org/10.1080/13504622.2014.888401

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. *Routledge*. https://doi.org/10.4324/9780203771587

Činčera, J., & Holec, J. (2016). Terénní výuka ve formální vzdělávání [Field-based instruction in formal education]. *Envigogika*, *11*(2). http://dx.doi.org/10.14712/18023061.533


https://doi.org/10.33225/jbse/25.24.1061

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Douglas, B., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Dünser, B., Möller, A., Anđić, B., Lampert, P., Bergmann-Gering, A., & Pany, P. (2024a). (Re)growing plant awareness: A Delphi study. *Plants, People, Planet*, *7*(4), 1055–1069. https://doi.org/10.1002/ppp3.10617

Dünser, B., Möller, A., Fondriest, V., Boeckle, M., Lampert, P., & Pany, P. (2024b). Attitudes towards plants – exploring the role of plants' ecosystem services. *Journal of Biological Education, 59*(1), 124–138. https://doi.org/10.1080/00219266.2024.2308293

Ellison, D., Morris, C.E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., Noordwijk, M., Creed, I. F., Pokorny, J., Gaveau, D., Spracklen, D. V., Tobella, A. B., Ilstedt, U., Teuling, A. J., Gebrehiwot, S. G., Sands, D. C., Muys, B., Verbist, B., Springgay, E., ... & Sullivan, C. A. (2017). Trees, forests and water: Cool insights for a hot world. *Global Environmental Change*, *43*, 51–61. https://doi.org/10.1016/j.gloenvcha.2017.01.002

Ellison, D., Pokorný, J., & Wild, M. (2024). Even cooler insights: On the power of forests to cool the planet. *Global Change Biology*, *30*(2), Article 17195. https://doi.org/10.1111/gcb.17195

Fančovičová, J., & Prokop, P. (2011). Plants have a chance: Outdoor educational programme applied in elementary school. *International Journal of Science Education*, *17*(4), 537–551. https://doi.org/10.1080/13504622.2010.545874

Frick, J., Kaiser, F. G., & Wilson, M. (2004). Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. *Personality and Individual Differences*, *37*(8), 1597–1613. https://doi.org/10.1016/j.paid.2004.02.015

Haglund, J., Fredrik, J., & Schönborn, K. J. (2022). *Thermal Cameras in Science Education.* In: Innovations in Science Education in Technology, Springer Cham. https://doi.org/10.1007/978-3-030-85288-7

Howard, T., Ougham, H., & Sanders, D. (2022). Plant blindness and sustainability. *International Journal of Sustainability in Higher Education*, *23*(1), 41–57. https://doi.org/10.1108/IJSHE-09-2020-0335

Kaldi, S., Filippatou, D., & Govaris, Ch. (2011). Project-based learning in primary schools: Effects on pupils' learning and attitudes. *Education*, *39*(1), 35–47. https://doi.org/10.1080/03004270903179538

Karaçalli, S., & Korur, F. (2014). The effects of project-based learning on students' academic achievement, attitude and retention of knowledge: The subject of "Electricity in our lives". *School Science and Mathematics*, *114*(5), 224–235. https://doi.org/10.1111/ssm.12071

Kaur, D., & Zhao, Y. (2017). Development of physics attitude scale (PAS): An instrument to measure students' attitudes toward physics. *The Asia-Pacific Education Researcher*, *26*(5), 291–304. https://doi.org/10.1007/s40299-017-0349-y

Kortam, N., Basheer, A., Hofstein, A., & Hugerat, M. (2018). How project-based learning promotes 7th grade students' motivation and attitudes towards studying biology. *Action Research and Innovation in Science Education*, *1*(2), 9–17. https://doi.org/10.51724/arise.10

Kravčik, M., Pokorný, J., & Kohutiar, J. (2008). Water for the recovery of the climate — A new water paradigm. Typopress Publishing House. https://www.academia.edu/10319837/The_New_Water_Paradigm_WATER_FOR_THE_RECOVERY_OF_THE_CLIMATE

Kubiatko, M., Fančovičová, J., & Prokop, P. (2021). Factual knowledge of students about plants is associated with attitudes and interest in botany. *International Journal of Science Education*, *43*(9), 1426–1440. https://doi.org/10.1080/09500693.2021.1917790

Marcos-Walias, J., Bobo-Pinilla, J., Delgado Inglesias, J., & Reinoso Tapia, R., (2023). Plant awareness disparity among students of different educational levels in Spain. *European Journal of Science and Mathematics Education*, *11*(2), 234–248. https://doi.org/10.30935/scimath/12570

Millennium Ecosystem Assessment (MEA), (2005). Ecosystems and human well-being: Synthesis. Island Press. http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Olejnik, S., & Algina, J. (2003). Generalized Eta and Omega Squared statistics: Measures of effect size for some common research designs. *Psychological Methods*, *8*(4), 434–447. https://doi.org/10.1037/1082-989x.8.4.434

Pany, P., Lörnitzo, A., Auleitner, L., Heidinger, C., Lampert, P., & Kiehn, M. (2019). Using students' interest in useful plants to encourage plant vision in the classroom. *Plants, People, Planet*, *1*(3), 261–270. https://doi.org/10.1002/ppp3.43

Pany, P., Meier, F. D., Dünser, B., Yanagida, T., Kiehn, M., & Möller, A. (2022). Measuring students' plant awareness: A prerequisite for effective botany education. *Journal of Biological Education*, *58*(5), 1–14. https://doi.org/10.1080/00219266.2022.2159491

Parsley, K. M. (2020). Plant awareness disparity: A case for renaming plant blindness. *Plants, People, Planet*, *2*(6), 598–601. https://doi.org/10.1002/ppp3.10153

Parsley, K. M., Daigle, B. J., & Sabel, J. L. (2022). Initial development and validation of the Plant Awareness Disparity Index. *CBE Life Sciences Education*, *21*(4). https://doi.org/10.1187/cbe.20-12-0275

Pedrera, O., Ortega-Lasuen, U., Ruiz-González, A., Díez, J. R., & Barrutia, O. (2023). Branches of plant blindness and their relationship with biodiversity conceptualisation among secondary students. *Journal of Biological Education*, *57*(3), 566–591. https://doi.org/10.1080/00219266.2021.1933133

Reschke, T., Lobinger, T., & Reschke, K. (2024), Short-term effectiveness of a brief psychological intervention on university students' stress and well-being during prolonged exam preparation: results of a randomized controlled trial. *Cogent Education, 11*(1). https://doi.org/10.1080/2331186X.2024.2354663

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Young Choi, M., Sanders, D., & Benefield, P. (2004). A review of research on outdoor learning. National Foundation for Educational Research and King's College London. *Field Studies Council*, 68.

Roczen, N., Kaiser, F. G., Bogner, F. X., & Wilson, M. (2014). A competence model for environmental education. *Environment and Behavior*, *46*(8), 972–992. https://doi.org/10.1177/0013916513492416

Ryplová, R., & Pokorný, J. (2018). Using project-based education to develop pre-service biology teachers' knowledge of the cooling effect of vegetation. In: M. Rusek & K. Vojir (Eds.), Project-based Education and Other Activating Strategies in Science Education XVI (pp. 105–113). Charles University.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Ryplová R. & Pokorný J. (2019). Opomíjená úloha vegetace v distribuci sluneční energie a utváření klimatu – sonda znalostí začínajících studentů učitelství přírodopisu [Ignored role of vegetation in the distribution of solar energy and climate formation – A survey of the knowledge of novice pre-service science teachers]. *Envigogika*, *14*(1), 1–19. https://doi.org/10.14712/18023061.586

Ryplová, R., & Pokorný, J. (2020). Saving water for the future via increasing plant literacy of pupils. *European Journal of Sustainable Development*, *9*(3), 313–323. https://doi.org/10.14207/ejsd.2020.v9n3p313

Stagg, B. C., & Dillon, J. (2022). Plant awareness is linked to plant relevance: A review of educational and ethnobiological literature (1998–2020). *Plants, People, Planet*, *4*(6), 579–592. https://doi.org/10.1002/ppp3.10323

Stagg, B. C., Hetherington, L., & Dillon, J. (2025). Towards a model of plant awareness in education: A literature review and framework proposal. *International Journal of Science Education*, *47*(4), 539–559. https://doi.org/10.1080/09500693.2024.2342575

Tatar, D., & Robinson, M. (2003). Use of digital cameras to increase student interest and learning in high school biology. *Journal of Science Education and Technology*, *12*(2), 89–95. https://doi.org/10.1023/A:1023930107732

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Tseng, K. H., Chang, C. C., Lou, S. J., & Chen, W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in project-based learning. *International Journal of Technology and Design Education*, *23*, 87–102. https://doi.org/10.1007/s10798-011-9160-x

UNESCO. (2017). *Education for Sustainable Development Goals: Learning Objectives*. https://unesdoc.unesco.org/ark:/48223/pf0000247444

Wandersee, J. H., & Schussler, E. E. (1999). Preventing plant blindness. *The American Biology Teacher*, *61*(2), 82–86. https://doi.org/10.2307/4450624

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